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OUR RECENT FLOODS.

BY J. W. POWELL, LL.D., DIRECTOR OF THE UNITED STATES GEOLOGICAL SURVEY.

DURING the past season floods have devastated many valleys in the United States. The Mississippi and most of its tributaries have poured tides of destruction over their adjacent lands. These floods extended over an area so widespread, involved so many river valleys, were poured down so many mountain sides and hill sides, and presented so many characteristics, that they cannot be succinctly and fully described within the inexorable limits of a magazine article. The destruction was equal to that of some memorable wars. In the northeastern portion of the flood invasion, on a tributary of the Alleghany at the sources of the Ohio, renowned for its quiet beauty, the moloch of fire joined with the dragon of flood in the work of destruction. In the rocks of northwestern Pennsylvania there are reservoirs of oil, stored by nature so long ago that years furnish no measure of the period intervening between that and the present time. From this store modern enterprise had gathered the oil into tanks, that the powers of fire might be used for industrial purposes,—smelting ores, driving engines, lighting cities, and warming cottage homes. But the flood came and these fossil fires stored by man in artificial reservoirs were turned loose to join with the floods in the work of destruction, so that flood and flame reveled as rival demons in the work. Thus tragedy joined hands with tragedy. The fire was but an accident of the flood, and the flood of the little Pennsylvania valley was but one of hundreds that devastated regions of country widely spread through much of the drainage basin of the Mississippi.

The amount of water which circulates through the air is immense. From year to year the total evaporation from land

and sea, and the total precipitation from the heavens to the surface, must be equal. The total amount of evaporation, and of consequent rainfall, is not exactly known, but the approximate amount is pretty well made out. The rate of evaporation has been measured in very many places scattered over the earth, especially in Europe and the United States, There are some places in the United States where evaporation is not more than 20 inches annually, but there are other regions, as in the lower valley of the Colorado River, where it is more than eight feet. These facts well illustrate the variability of evaporation.

But more attention has been given to the measurement of rainfall than to the measurement of evaporation. Like the latter, it is variable, ranging from less than an inch to more than 50 feet annually. On the Mohave desert the rainfall is about three inches, and in various portions of the United States this increases to 10, 20, 30, 50 inches, until in the northwestern part of the State of Washington there is a rainfall of 125 inches in a single year. On the peninsula of India the rainfall varies from 74 to 255 inches annually, and at Cossyah, north of Calcutta, there is said to be an annual rainfall of 610 inches. Thus rainfall, like evaporation, varies from land to land between great extremes. In general, there is a decrease of rainfall from the equator to the poles. The following table is a fair approximation of the amount of rainfall in zones of latitude receding from the equator :

AVERAGE ANNUAL RAINFALL IN DIFFERENT LATITUDES.

Latitude.	Inches of rain.
0	100
20	80
30	60
40	40
50	30
60	20
70	10
80	5

The average rainfall for the entire surface of the earth is about four feet. The entire annual rainfall upon the earth is estimated at about 152,000 cubic miles. This is sufficient to fill Lake Erie nearly 900 times or Lake Superior 50 times. These figures give a fair idea of the amount of water which is anually carried to the clouds and discharged upon the earth, and of the energy exerted in the work by the heat of the sun.

It has been seen that the rainfall is very unequally distributed over the surface of the earth ; that some lands reap a great harvest from the clouds , others a meager supply. But such inequality does not produce floods. If the rainfall were distributed equally through the days, or even through the months of the year, there would be no disastrous floods. Regular rainfall produces regular channels competent to carry away all the water. There are floods in arid lands and in humid lands alike. One of the floods last year, which made a lake in a desert, was in a region of minimum rainfall. It is the concentration of rain in brief intervals of time that brings disastrous floods. In France 31 inches of rain have been observed to fall in thirty-four hours ; in Genoa, 30 inches in 24 hours ; in Gibraltar, 33 inches in thirty-six hours ; near Bombay, 24 inches in one night ; on the Khasi in India, 150 inches have fallen in five successive days. There are on record in the United States several instances of a fall of five or six inches in two or three hours. A great rainfall may extend over a great area of country, but oftener extreme rainfalls are limited to small districts, sometimes to only a very few square miles. Thus there are great regional floods and very local floods.

Can man control these mighty powers ? Man cannot hide the earth from the sun, and its powers of lifting the waters are beyond his control. By the heat of the sun and the revolution of the earth winds are set in motion, and they cannot be stayed by the puny power of man. Under these conditions the clouds gather and dance in aërial revelry and rain where they will. The energy exhibited in one shower that sweeps over a county of meadows is greater than the power of the falls of Niagara.

But rains are not solely powers of destruction ; they are the fertilizers of the soil, the beneficent harbingers of harvest. Forests bourgeon in their bounty, meadows luxuriate in their gifts, orchards blossom in their balm, vineyards quaff their nectar for a transformed vintage. Thus there are rains of delight and storms of terror. Where storms prevail jungles grow, where storms fail deserts are found, and desert and jungle alike are enemies of man. So man longs for gentle and frequent rains.

It has been the dream of mankind to control the clouds. Savage men dance for rain, and beat drums, and deck altars with the plumes of birds, and smoke pipes to create mimic clouds, and make offerings of meal to the wind gods, and perform long dramatic ceremonies as they pray for rain. All savage tribes thus seek to govern the clouds with terpsichorean worship. Barbaric men still keep up their dancing and their singing and their ceremonies, but to them they add costly offerings—libations of wine and hecatombs of beasts and human sacrifices—thus conjoining sacrificial with terpsichorean worship. Early civilized men still perform ceremonies, still make sacrifices, but to them they add a newer form of supplication in confessions of belief in the power, goodness, and glory of the rain gods. But terpsichorean, sacrificial, and fiducial agencies fail to change the desert into the garden or to transform the flood-storm into the refreshing shower. Years of drought and famine come, and years of flood and famine come, and the climate is not changed with dance, libation, or prayer.

Now great is the name of science! In the elder day if a man would palm upon the world an elixir of life or a universal panacea he did it in the name of religion. To the skirts of religion all humbug and villainy clung. In modern times religion has shaken off these vampires, and they now cling to science. If any man has an elixir or a panacea or any other monstrous humbug he clings to the garments of science, and claims to have discovered some great scientific principle. For it must be scientific or it is nothing.

It is a glorious sight to see a man in the possession of an idea, for the great idea exalts the man; but it is a sorry sight to see an idea in the possession of a man. Some ideas are like devil-fish, they wind themselves about their victims, who writhe in agony and exclaim: "How great is this idea, it is science itself!" Now and then in modern civilization some man in the gripe of an idea howls about the scientific principle which he has discovered. Among the ailments of life rheumatism and fits are the ills over which he most often claims control, and among the powers of nature earthquakes and storms are the ones over which he most often claims control. The man in the possession of the earthquake fiend we have all known, and the man in the possession of the storm-devil idea is not uncommon. There are those who would control the rains and change the climate by boring artesian wells; there are those who would control the clouds by planting trees and preserving forests; there are those who would change the climate by building railroads, and there are those who would control the rains by bombarding the heavens with popgun balloons. When you meet with one of these men you may always know that a devil-fish has seized him. Such errors often have a subtle power over the mind by reason of the modicum of truth which they contain.

There are districts in various parts of the world where artesian fountains may be found whose waters are a blessing to mankind, furnishing needed supplies for men and animals and sometimes for power. In arid lands they are especially beneficent, where they can be used for cultivating gardens, vineyards, and orchards. Wherever they are found they prove to be of great value. But when it is claimed, as it has been again and again, that such waters can be brought to the surface and used in irrigation and evaporated to the heavens, and that the moisture will change the climate, there is a singular misapprehension of quantitative relations. How many artesian wells would it require to furnish the water for a monthly rain ? and who could prevent waters furnished to the atmosphere in this manner from drifting away with the air currents to lands where rains are not needed ?

Every man loves to see trees scattered over the landscape for their beauty and for their usefulness, and there is no sadder sight than that presented by the destruction of forests by fire or wanton axemen. When the slopes of plains, hills, and mountains are denuded of forests, especially by fire, they are attacked by rains and channeled by the streams, and the fertile soils are swept away until desolation prevails. The forests annually destroyed by fire in the United States are of great extent, and values by the million are thus transformed into smoke. The planting of trees and the protection of forests are ends worthy to be attained, yet men go wild with their theories and claim that they can change climates thereby. Some minute effects on evaporation and precipitation may be possible, but such effects compared with the great powers of nature in producing rain are too insignificant to be worthy of consideration.

It is possible that when the atmosphere is charged with moisture mechanical agencies could be devised by which some small portion of the rainfall could be precipitated—a few drops over a bit of land ; but making noises overhead does not bring the water up from the sea; it does not fill the dry air with moisture; and it cannot discharge from a saturated body of air such a quantity of moisture as would be of any value to thirsty fields. Before science can do anything of value to man in the control of winds and storms it must learn to control powers of a magnitude almost beyond human imagination. Yet here something can be done of value to the mariner and the agriculturist. Scientific men are investigating the laws of meteorology, and have already discovered much of value, so that it has become possible, and more and more practicable, to foretell meteorological conditions, and by wise prevision to avert calamity.

Can anything be done to prevent floods or to ameliorate them, or is human endeavor restricted to the work of predicting impending disaster and fleeing from it? The subject is worthy of a little further consideration.

The rain which falls upon the land so irregularly is in part evaporated and in part flows to the sea by rivers. The percentage of river-flow is quite variable in different countries. In the arid portion of the United States there are hundreds of creeks and small rivers whose waters roll out into desert sands where they are evaporated. In this region of country very little of the rainfall is carried to the sea. The great rivers are few, and the few are very small when compared with the areas drained. While thus there are extended districts from which no water runs to the sea, there are others where the river-flow is a large percentage of the rainfall.

The following table shows the proportion which the discharge bears to rainfall in several basins in the United States:

Connecticut River	63	per cent.
Croton River, N. Y.	51	" "
Sudbury River, Mass.	48	" "
All rivers of Maine, average	40	" "
Entire Mississippi, excluding Red River	25	" "
Ohio River	24	" "
Upper Mississippi	24	" "
Missouri River	15	" "
Arkansas River	15	" "
Red River, Louisiana	20	" "

From the above facts it will be seen that it is not necessary to control all the rainfall of a basin in order to control the floods of its river. Again, the river will normally take care of the greater part of its discharge. The channel itself is adequate to the task of carrying away the water of any ordinary rain. Every destructive flood is caused by the comparatively small excess of a storm which is of unusual magnitude. Thus while the quantity of water which appears in any great flood is vast, yet that which brings destruction is only the excess over the carrying capacity of the channel. The destructive waters, therefore, are but a very small percentage of the rainfall, and but a small percentage of the river-flow. The quantities of water to be controlled and the powers to be mastered are so nearly within the conditions where human effort may be available that hydraulic engineers and geologists have again and again considered this problem, not without hope of its solution.

Let us see what the problem is, how it varies from region to region, and to what extent it is affected by the operations of man. The rivers of the earth may be divided into two classes, namely, flood-plain rivers and cañon rivers. In flood-plain rivers under conditions of great precipitation the waters rise above the channel banks to overflow the plain which descends seaward or towards the mouth of the river. In cañon streams the channels are cut so deep that the highest flood never reaches the brink of the cañon walls. There are many rivers which are flood-plain streams along parts of their courses and cañon streams along other parts of their courses. In cañon channels it is evident that human habitations and property are safe when above the flood-line, and this flood-line is always easily discernible, so that little excuse is found for those who suffer from floods under such conditions. But a great majority of rivers are flood-plain streams, and here the conditions of safety are not so readily discovered. A great river ramifies into small rivers and these ramify into creeks, and the creeks into brooks. Along the course of such a tree-of-rivers all those parts which are not cañon-reaches have flood-plains,—that is, comparatively level stretches, back from the river, on either side to the foot of the hills.

This flood-plain receives the excessive waters when the river overflows its banks, and the sediment carried by the river is deposited over the plain. This deposit makes the soil rich, and the most fertile lands of the world are along flood-plains. The whole extent of the flood-plains of any reach of a river is not usually conspicuous to the untrained eye. The lower portions are readily recognized as such by all, but the higher portions, which are submerged only by the great floods that come perhaps many years apart, are usually unrecognized by non-experts; but they are easily discovered by trained geologists, for the deposited strata are clearly differentiated from the hill strata on either side. In a great river, with its tributaries, it will be noticed that above the point where the streams are small the channels of the rivers descend abruptly, and the flood-plains on either side also descend down stream at a comparatively high rate. But as the river grows larger the channel and the flood-plain have less declivity, until when near the sea they have but a low slope. In the small streams at the headwaters of the Ohio and in other tributaries of the Mississippi the declivities may be many feet to the mile, but the Mississippi River itself and its flood-plain on either side from the Ohio to the Gulf have a descent which is not greater than four inches to the mile. These low declivities near the sea are usually called delta plains. But the torrential plains above are not clearly demarcated from the delta plains below, torrent-stretch merging into delta-stretch; yet these two portions of any great river present very different problems.

In the torrential portion of the river's course the flood-plain is narrow; in the delta portion the flood-plain is wide. In the torrential portion the stream may be cutting its channel deeper from year to year. but in the delta portion the river can never cut its channel deeper, or, as the geologist says, corrade vertically. Wherever there is a flood-plain along the river the stream cuts its banks, or corrades laterally, in the language of the geologist. In torrential regions corrasion is thus both vertical and lateral, but in delta regions corrasion is wholly lateral. These conditions of corrasion present widely differentiated problems to the engineer. By lateral corrasion a flood-plain stream changes its course, wandering over the plain by cutting banks on one side and building banks on the other. So a river meanders back and forth through its valley as the years go on, changing its site. Where the river runs to-day a bank will be built to-morrow, and where a bank stands to-day a river channel will be cut to-morrow. In a state of nature this squirming of the river is comparatively slow, but on the first settlement of a country it is greatly accelerated. The cause may be indicated as follows: The clearing of the forests, the plowing of the fields, the opening of roads, and various other operations performed by man, greatly stimulate the wash. Detritus added to a stream in this manner chokes it, and bars and low dams are formed by the additional mud and sand. The river thus checked turns against its banks and cuts them, now on this side, now on that. The cutting of the bank loads it with more material, again to choke some reach below, and this cutting and choking of the stream and turning it from its course is repeated again and again as it makes its way to the sea.

Now as flood-plain streams are choked in this manner floods ar increased, for the water is thus sooner turned from its channel. Again, as the currents of the stream are increased, the curves of the stream are multiplied, the course of the river is lengthened, and the declivity of the channel diminished ; and so destructive floods are still further multiplied.

A time arrives when this growth in floods caused by human operations comes to an end. The new channels cut by men are lined with willows, grasses, and various other plants, and cease to wash. By higher cultivation the fields are not left exposed to destruction by rains, rills, and brooks ; and gradually man learns to clear the river channels from obstructions. In a high state of cultivation and civilization it is probable that river channels carry away the waters of floods quite as rapidly as, perhaps often more successfully than, in a state of nature.

There has grown up in this country another agency which is ultimately to affect the regimen of rivers. Its effect is already to be observed in the arid region. This comes from the utilization of waters for irrigation. It may be expected that in the near future all of the rivers of the arid region—about two-fifths of the entire area of the United States—will be controlled for purposes of irrigation ; all the flood waters will be caught and stored, and all that vast empire will be free from the threatening terrors of flood. This will not happen through any immense engineering works devised to control the rivers themselves, but it will come by controlling in detail the smaller streams that unite to make the rivers. The Missouri River and most of its tributaries on the western side will ultimately all be used for irrigation, and much relief from floods will result therefrom, to be felt even in the lower valley of the Mississippi.

Of the three great rivers that unite to form the Mississippi, namely, the Ohio, the upper Mississippi, and the Missouri, the Missouri is much the longest, but it carries a small volume of water compared with the others, so that the control of the Missouri will not so greatly affect the volume of water in the lower Mississippi. On the other hand, the Missouri supplies about nine-tenths of the detritus to the lower Mississippi, and furnishes the obstructions that choke it. Ultimately irrigation will do much to correct this flow. Irrigation is not confined to arid regions. Of late years, especially in Europe, its chief growth is in humid regions. Mineral and other artificial fertilizers are not inexhaustible. The water which flows from the hills above is inexhaustible, and far more valuable for fertilizing purposes than any other stimulant that man has devised. For this reason it may be expected that irrigation will be practised all over the United States. The valley of the Mississippi and the multitudinous valleys of the Appalachian Mountains and the Atlantic coast are well adapted to this enterprise, and soon we shall see every farmer carrying a little stream of water upon his land, and thereby greatly multiplying the products of the soil. All this will aid in the amelioration of floods.

There is still another agency by the aid of which good agriculture produces advantageous results. Deep cultivation and underdraining create a reservoir for water wherever it is practiced. By properly cultivating the lands, so that they will not be washed away by rains and rills, and by underdraining, so that reservoirs of water will be produced wherever fields are found, and by the use of the smaller streams in irrigation, some lands will be entirely relieved of floods, other lands will have their floods diminished, and in all cases some relief will result. But all of these agencies combined will not entirely protect the world from floods ; so the engineering problems remain.

Practically three methods of protection from floods have been advocated by engineers and geologists. One is to store the surplus waters in great artificial lakes. This plan was ably advocated for the Ohio River by Ellet, the engineer who built the rams on the Mississippi River, in an elaborate publication of the Smithsonian Institution. A second method which has been advocated is to shorten the courses of rivers by straightening their channels and opening shorter outlets to the sea. A third method is the one generally adopted; that is, the protection of flood-plains by embankments. All of these methods are expensive, and require vast engineering plans and years of heavy labor. In general, engineers seem to prefer the embankment system ; perhaps geologists are more generally inclined to the reservoir system. The merits of these several systems cannot here be discussed ; a volume would be necessary for their elucidation.

Meanwhile, is there no hope of relief from floods ? I think that a practical word of advice can be given. In the first place, the signal system of the Weather Bureau of the government can be developed in this direction to great advantage, so that people will be more thoroughly warned of coming floods. In the second place, on the torrential streams the flood-plains should be avoided—no town, no house, no barn should ever be built upon a flood-plain. The valleys are narrow, the hills are near by, and the dangerous lands can be easily pointed out by geologists. It would be vain to say that these torrential plains should not be cultivated, for they have the best soils, but they are ever subject to inundation and can be cultivated by man only on the condition that he will pay a tax every five, ten, or fifty years in the form of a destroyed crop. Yet the lands are superior and this tax can be paid. But it is almost criminal to subject homes to the terrors of flood, and it is a wholly unnecessary risk to barns, granaries, flocks, and herds. To build towns on torrential flood-plains in face of all the warnings which history has given is a folly. Every flood-plain must some time be inundated, and every house built upon a flood-plain must some time be swept away. Years may pass without a flood, but it comes at last.

On delta flood-plains, like that of the great valley of the Mississippi, other problems are presented. This one valley is an empire in area. Its soils are sources of incalculable wealth and men will cultivate them. The belt of plain is wide and it cannot be reached from the hills. But there are elevations in the midst of the plain that can be utilized as safe sites for homes, and artificial embankments can often be made to serve a good purpose.

The great problem remains. The whole subject of rains, rivers, floods, and flood-plains demands further investigation. The first need is for accurate topographic maps ; the second need is for geological surveys by which flood-plains are outlined ; the third need is for hydraulic surveys by which the rivers are gauged and the powers to be controlled are discovered. As the facts come to light American genius will solve the problem.

J. W. POWELL.